

On the Detection of Feature Points of 3D Facial Image and Its Application to 3D Facial Caricature

Takayuki Fujiwara+, Takeshi Nishihara+, Masafumi Tominaga+, Kunihiro Kato*,
Kazuhito Murakami++ and Hiroyasu Koshimizu+

+ SCCS, Chukyo University, 101 Tokodachi Kaizu-cho, Toyota-shi, 470-0393 JAPAN

* Faculty of Engineering, Gifu University, Japan

++ Faculty of I.S.T., Aichi Prefectural University, Japan

Abstract

This paper proposes an automated method for extracting 27 feature points from 3D facial image, and shows that 3D facial caricaturing can be realized by such these smaller number of feature points provide and that these 27 feature points could be extracted automatically.

As a result, it was clarified by comparing 3D caricature of 3D PICASSO system with that of a famous caricaturist Mr. Yoshida that 3D features of the facial image could be utilized to generate more impressive facial caricature than the 2D one.

1. Introduction

Facial caricature painters and illustrators catch characteristics of the face and its personality features clearly, and they draw the facial caricature by exaggerating them skillfully. As for their observation process, they extract the shape, size, color and emotions of the face, and they draw the caricature through the deformation process of these personal characteristics. It is easily known that these personality characteristics can be drawn by transforming them in the various ways of expressions as a facial caricature that is finally very sensitive to the KANSEI of the viewers.

In our laboratory, we are developing the facial caricature system which extract the characteristics of human face taken from the face image by the video camera, and deforms these characteristics. This 2D facial caricature deformation system PICASSO has been developed. And accordingly it is started to investigate that several extensions of the dimensionality of the facial expressions could be applicable to the facial caricature such as 3D

caricature, profile caricature, and motion caricature. Thus the scope of the individuality features of the face could be extended to the 3 dimensional shape of the face such as the height of the nose, and this means 3D range data of the face.

In this paper, automatic detection of the regions covering each facial parts is introduced in order to realize 3D facial caricaturing system. The 3D facial caricature which make individuality features reflect more sensitive by in dimension can be realized by introducing the polygon mask defined by the feature points extracted from 3D facial image. Up to now, this 3D facial caricaturing system was developed by using 189 feature points which are provided mainly by the hand-operated works. This paper proposed an automatic method to detect feature points and 27 and/or 39 effective feature points could be extracted automatically. Consequently, it was clarified that 3D facial caricature could be realized without hand-operation to get the facial feature points, and that 3D facial caricature could be more impressive to the viewers than 2D one.

In chap.2, the property of the spatial dimension of the face data was investigated and the principle of PICASSO system was summarized. In chap.3, the details of the method to extract feature points was presented, and in chap.4 3D facial caricaturing system was introduced and its validity was clarified experimentally.

2. Data dimension in facial caricature

2.1. Human illustrator and 2D-PICASSO

First, two facial caricatures are shown in Fig.1. 2D-PICASSO system (P-program) made the Fig.1(a) and a famous illustrator Mr. Katsuhiko Yoshida (Y-

BEST AVAILABLE COPY

program) drew the Fig.1(b) as the facial caricature of Prince Charles of Wales. This caricature gave us a chance to start this investigation [1][4], and the reason for this chance can be summarized as follows:

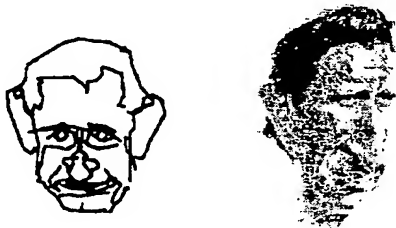
The impressions for this work can be shortly analyzed as follows:

*Appearant differences of the information media are in line drawing vs. color & gray and in 2D vs. 3D dimensionality.

*We can't know whether the mechanisms to extract and deform the facial features are similar or not.

*Nevertheless, it was strongly impressive that P-program and Y-program for facial caricaturing have the very similar ways, for example at around the inflating cheek and at the pair of eyes and eye brows.

As a result, human-like KANSEI for facial caricaturing could be given to the computer system PICASSO and computer-like logic for facial caricaturing should be working in the human illustrator.



(a) PICASSO (b) Mr. Katsuhiko Yoshida

Fig.1 Facial caricatures of Prince Charles of Wales.

2.2. "Average face" assumption the facial caricaturing and PICASSO system

In PICASSO system, "Project for Intelligent Caricaturing Sophisticated System-One", the human face images are inputted to the computer, and the system recognizes where and how much the personal characteristic features are in the face, and finally the system exaggerate them for generating the caricature.

As for the basic principle of PICASSO, the facial caricature Q_{2D} could be generated by comparing the input face P_{2D} with the average face S_{2D} which is define by the averaging procedure for a set of input faces. We call this idea as "average face assumption" for facial caricaturing. The general idea figure of this PICASSO is shown in Fig.2.

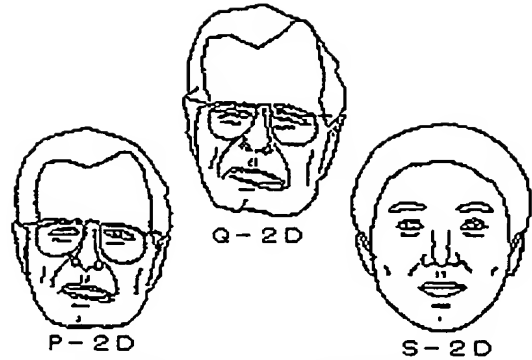


Fig.2 The principle of 2D-PICASSO.

Facial caricature Q_{2D} is generated from the input face P_{2D} by comparing with the average face S_{2D} in the equation below. In this formalism, the individuality features can be expressed by the vector $(P_{2D} - S_{2D})$, and the parameter b indicates the deformation rate.

$$Q_{2D} = P_{2D} + b(P_{2D} - S_{2D}) \quad (1)$$

We are going to realize the practical PICASSO system in such a way that as a person sits in front of the camera, then the facial caricature Q_{2D} is generated suitably to the viewer's visual KANSEI.

Next, the rough flow of the 3D facial caricaturing and its principle are introduced here. First, the original 3D face data is taken by using range camera, and the facial caricaturing is executed as follows. After the preprocessing of facial parts, the face data is normalized by Affine transform for adjusting several kinds of input faces. Through this preprocessing, the input data P_{3D} are available to introduce the "average 3D face" S_{3D} . The difference between $(P_{3D} - S_{3D})$ can be utilized to generate 3D facial caricature Q_{3D} as given in the following equation. This general idea of this 3D facial caricaturing is shown in Fig.3. This figure draws that a 3D facial caricature Q_{3D} is generated from the average face S_{3D} and the input face P_{3D} .

Thus, the fundamental principle of 3D caricaturing is the same as the 2D facial caricaturing and it is formalized with the equation:

$$Q_{3D} = P_{3D} + b(P_{3D} - S_{3D}) \quad (2)$$

Two types of input data were used, first one is the 3D range face data and another is the grey image completely registrated with each other. By using this augmentation of the face dimensionality, the shape of the 3D appearance of them are precisely acquired and 3D impressions of the face could be effectively exaggerated in the caricature.

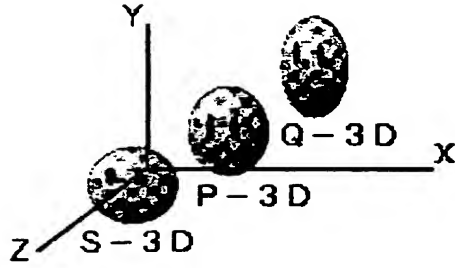


Fig.3 General idea of the 3D face caricaturing.

3. Automatic detection of facial parts region

3.1. Detection method of nose region

The origin of the image is taken at the upper left, and x axis is taken in the horizontal direction, and y axis is taken in the vertical direction. The x, y coordinate which gives the maximum value $f^{(u)}_{\max}$ of the 3D range image defined by eq.(3) becomes a nose apex (x_{\max}, y_{\max}).

$$f^{(u)} = \{f^{(u)}_{xy} \mid 1 \leq x \leq 256, 1 \leq y \leq 240\} \quad (3)$$

An example is shown in Fig. 4



Fig.4 Example for macroscopic extrema.

Next, the curvature of the range data acquired along the y axis direction is investigated from (x_{\max}, y_{\max}), and the macroscopic extrema defined eq.(4) located upward are found.

$$(x_{\max}, y_u^{(u)})(u=1,2,3), (x_{\max}, y_b^{(b)})(b=1,2,\dots,7) \quad (4)$$

An example of these extrema is shown in Fig.4. Then, a pair of lines passing through the first two macroscopic extrema $y=y_u^{(1)}$ and $y=y_b^{(1)}$ are recognized as the horizontal line pair of the nose region. Scanning the range data in the x direction from the point of nose

apex, two points $x_{(L,nb)}, x_{(R,nb)}$ where the range value becomes greater than the threshold can be extracted as the vertical line pair of the nose region. In other words, the nose region is defined by eq.(5).

$$\{(x,y) \mid x_{(L,nb)} \leq x \leq x_{(R,nb)}, y_{(U,nb)} \leq y \leq y_{(B,nb)}\} \quad (5)$$

An example is shown in Fig. 5.



Fig.5 Detection method of nose region.

3.2. Detection method of the mouth region

The pair of the horizontal boundaries of the mouth region are defined by the pair of the vertical boundaries of the mouth region which are defined by a pair of lines passing through the points $x_{(L,m)}$ and $x_{(R,m)}$. These two points are the first points where the gradient value of the range data becomes greater than the threshold. In other words, the mouth region is defined by eq.(6).

$$\{(x,y) \mid x_{(L,m)} \leq x \leq x_{(R,m)}, y_{(U,m)} \leq y \leq y_{(B,m)}\} \quad (6)$$

An example is shown in Fig.6.

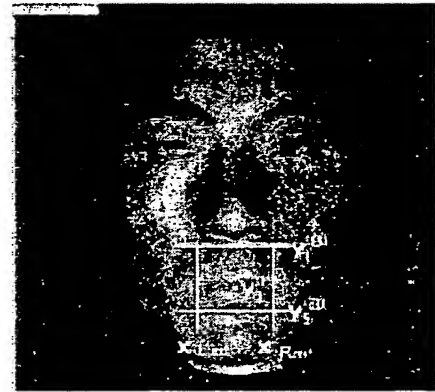


Fig.6 Detection method of mouth region.

3.3. Detection method of the eye region

The upper and lower boundaries of the eye region are defined by the $y_2^{(U)}$ and the middle of y_{\max} and $y_1^{(U)}$ respectively, the left and right boundaries are defined by a pair of lines passing through the two terminal points $x_{(L)}^{(U)}$ and $x_{(R)}^{(U)}$ of the face range image. In other words, the eye region is defined by eq.(7).

$$\{(x,y) \mid x_{(L)}^{(U)} \leq x \leq x_{(R)}^{(U)}, y_{0.5}^{(U)} \leq y \leq y_2^{(U)}\} \quad (7)$$

An example is shown in Fig.7.

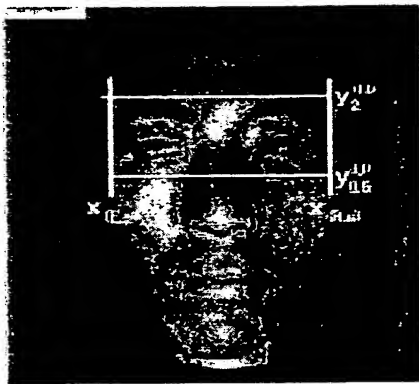


Fig.7 Detection method of eye region.

3.4. Making triangular patch and 3D average face

The 3D surface of the face was constructed by introducing triangular patches defined on the feature points defined in Chap.'s 3.1, 3.2 and 3.3. Triangular patch was formed by using these feature points $(x_i, y_i, z_i), z_i = f(x_i, y_i), i = 1, 2, \dots, N$ ($N=27$ in this experiment). The number of patches is 50 and each patch is corresponding among the different faces, and each 3D surface data is normalized by Affine transform. Fig.8 shows an example.

Within each triangular patch, the range data of the pixel are assembled and the average range value of the pixel is introduced by the following equation(8). Basing on these average range data $(x_{(i)}^{(s)}, y_{(i)}^{(s)}, z_{(i)}^{(s)})$, "3D average face" S_{3d} can be defined and Fig.9 shows a couple of examples.

$$x_i^{(s)} = \frac{1}{N} \sum_{j=1}^N x_i^{(j)}, y_i^{(s)} = \frac{1}{N} \sum_{j=1}^N y_i^{(j)}, z_i^{(s)} = \frac{1}{N} \sum_{j=1}^N z_i^{(j)} \quad (8)$$

Let us compare the average face given above with the average face introduced manually with 189 feature points, in order to show the feasibility of the proposed method of this paper. Fig.10 shows an example of the previous method with 189 feature points. Even by the proposed method with 27 feature

points, the facial surface could be successfully expressed except at the boundaries of the hair, where the range data can not be originally aquired. In addition to this, as all 27 feature points can be extracted automatically, it is obvious that the proposed method would be superior to the previous one.

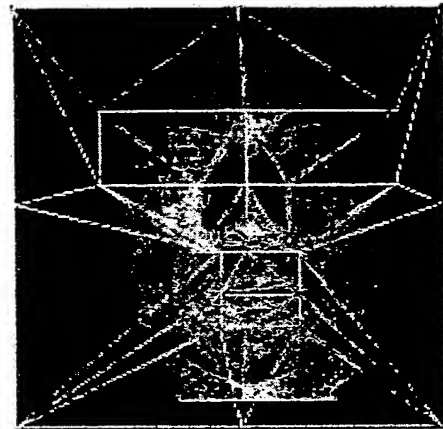


Fig.8 Example of the triangular patches.

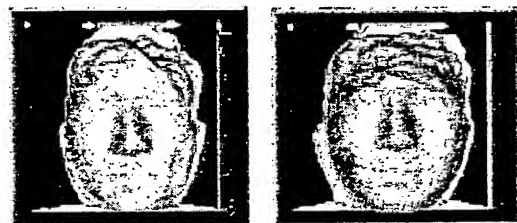


Fig.9 3D average faces defined by 8 persons and 16 persons.

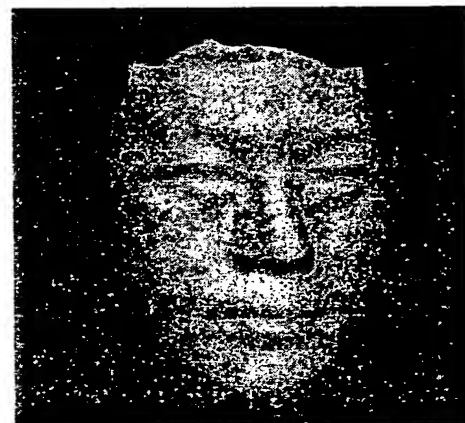


Fig.10 Average face of 189 points

4. 3D facial caricaturing

4.1. Method of 3D facial caricaturing

3 vertexes $(x_{(j)}^{(q)}, y_{(j)}^{(q)}) (j=1,2,3)$ of the facial caricature Q are calculated by partitioning the face every triangle patch of the input face P , based on 3 vertexes $(x_{(j)}^{(p)}, y_{(j)}^{(p)}) (j=1,2,3)$ and 3 vertexes $(x_{(j)}^{(s)}, y_{(j)}^{(s)}) (j=1,2,3)$ of the average face S .

$$x_{(j)}^{(q)} = x_{(j)}^{(p)} + b(x_{(j)}^{(p)} - x_{(j)}^{(s)}) \quad (9)$$

$$y_{(j)}^{(q)} = y_{(j)}^{(p)} + b(y_{(j)}^{(p)} - y_{(j)}^{(s)}) \quad (10)$$

Height values of every pixel of the facial caricature Q are calculated by the input face P and average face S given in equation (11).

$$z_{(x,y)}^{(q)} = z_{(x,y)}^{(p)} + b(z_{(x,y)}^{(p)} - z_{(x,y)}^{(s)}) \quad (11)$$

4.2. Experimental result of facial caricaturing experiment

In this section, we will show the facial caricaturing experiments. We made the caricature using the average face shown in Fig.10. In this case, the facial caricatures was made with the value of deformation rate 100%.

3D facial caricaturing results are shown in Fig.11. Comparing these two facial caricatures, the respective facial individuality characteristics are successfully. For example, the cheeks of these caricatures are enhanced and this feature is common to these faces. We can get the good result, even if the feature points are decreased to 27, as shown by these experimental results. And this method has an advantage that the feature points are detected automatically, because the number of the feature point are very small.

5. Consideration

Considering about the way of making the average face, facial sketch of the 3D face can be automatically extracted quickly and 3D average face can be also generated automatically. In the previous method, we had to get the 189 feature points manually. And we can get the good average face, which could suppress the individual characteristics sufficiently, even if the number of the feature points is decreased to 27. Furthermore, it is possible to make the 3D caricature by using only 27 feature points (Fig.12).

Figure 13 shows the comparison of the caricature generated by our system with the caricature given by the human illustrator. We can see that both

caricatures are well deformed in the similar characteristics of this model.

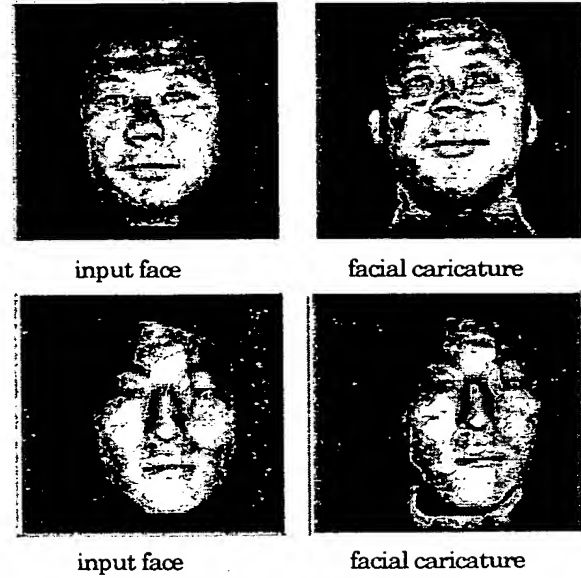


Fig.11 Results of 3D-PICASSO.

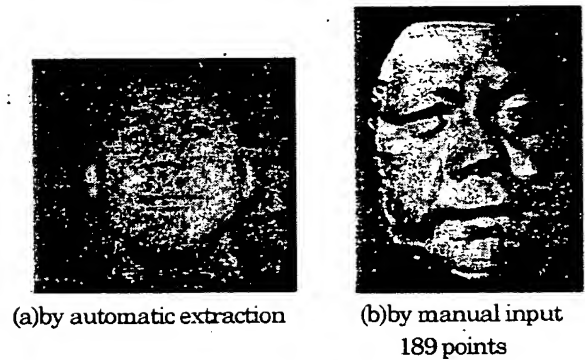


Fig.12 Comparison of facial caricatures of the each technique.

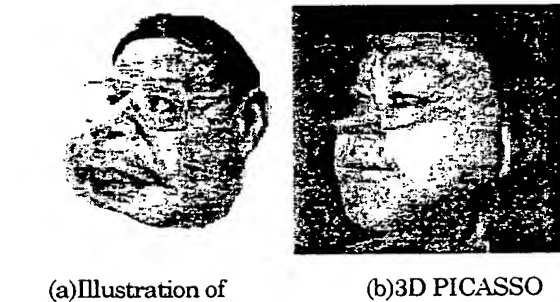


Fig.13 Comparison with the illustrator.

6. Improvement on the extraction of face outline

As the more effective alternative of the previous 189 points, a method to extract 27 points more than 189 points is presented. But there is shortage in this time set of 27 features to cover the part of head and jaw. Then in addition to this, some augmentation of the feature points was introduced to make the better facial caricature. To do this augmentation, 12 feature points for the outline of the jaw are introduced as shown in Fig.14.

When the origin of the image is taken at the apex of the nose, by scanning the image at $y=1$, $x=1$, $y=x$, $y=-x$, $y=2x$, $y=-2x$, $y=1/2$ and $y=-1/2$, feature points of outline of the jaw could be introduced. The result of the generated triangular patch is given in Fig.15.

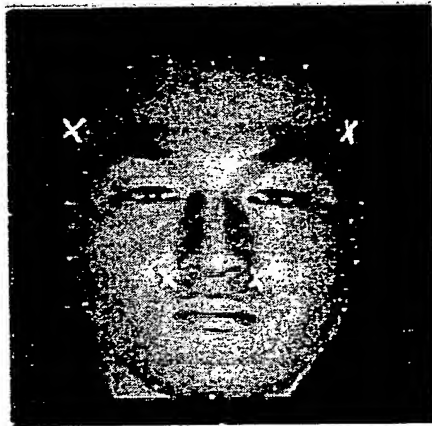


Fig.14 Augmentation of the feature points.

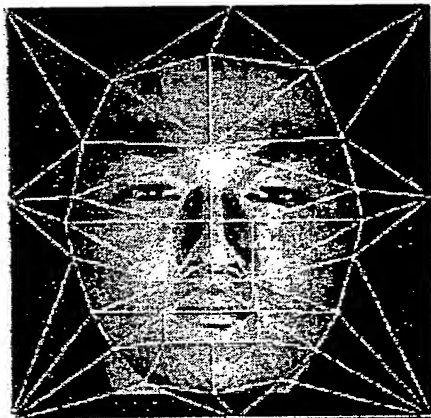


Fig.15 Results of 39 feature points.

7. Conclusion

This paper presented the methods for the preparation of the average face by the automatic feature points extraction of the characteristic point of the 3D face image, for the generation of the triangular patch and for the deformation of the facial caricature. But we have some following subjects to be solved. Until now, it was clarified that the input time about the facial caricature could be shortened by the automatic extraction of characteristic points. Yet, this method is not enough to realize the extraction precision and robustness of the characteristic point. For example, if the recognition precision could not be realized well at the apex of the nose, other characteristic points could not fatally be detected at the correct position. Therefore, it is necessary to enforce the extraction precision of the characteristic point. Furthermore, the quality of the 3D caricature should be improved by the automatic extraction of the characteristics points of the face outline.

Acknowledgement

We would like express many thanks for giving facial caricatures and helpful discussion to Mr. Katsuhiko Yoshida of Design Dep. SUNTORY and Mr. You Nakagawa of Tokyo Shinbun.

This paper was partially supported by Ministry of Education, High-Tech Research Center Promotion, and IMS HUTOP Research Promotion.

References

- [1] Symposium on Face Research, Japan Society of Facial Studies (1998.3.7)
- [2] Special issue on Face, Trans. IEICE, Vol.J80-D-II, No. 8, pp.1140-1146(1997.9)
- [3] Koshimizu, H.: Computer Facial Caricaturing, Trans. The Institute of Image Information and Television Engineers, Vol.51, No.8, pp.1140-1146(1997.8)
- [4] Nakagawa, Y.: First meeting of machine and illustrator, The evening edition of Tokyo Shinbun(1998.3.26)
- [5] Yamafuji, S.: Subjective deformation, (private letter)(1998.7.14)
- [6] Akasegawa, G.: The mystery of science, Quark, Vol. 163, pp.79-82(1997.1)
- [7] Koshimizu, H.: Be pioneer? Road to a computer

illustrator of Facial caricature, Cosmetics Culture (Kesho Bunka), Vol.37, pp.35-53(1997.11)

[8] Katsuhiko, Y.: A few complaints of an artist of facial caricature, Cosmetics Culture (Kesho Bunka), Vol.37, pp.70-73(1997.11)

[9] Koshimizu,H.: Discovering caricatured expression in language, Language (Gekkan Gengo), Vol.27, No.7, pp.4-5(1998.7)

[10] Nishihara,T., Tominaga,M., Sano,H., Murakami,K. and Koshimizu,H.: On the Detection of the Feature Points of 3D Facial Image and Its Application to 3D Facial Caricature, 1998 Annual Meeting of Electric Engineers in Tokai Branch(Sep.1998)

[11] Murakami,K., Koshimizu,H.: On the Facial Caricaturing System PICASSO with Visual Illusion, Trans. IPSJ, Vol.34, No.10, pp.2106-2116(1993.8)

[12] Tominaga,M., Jun-itiro,H., Murakami,K. and Koshimizu,H.: Motion Facial Caricature with Deformation of Emotion, Trans. IEICE, Vol.J81-D-II, No.8, pp.1856-1866(1998.8)

[13] Murakami,K., Tominaga,M. and Koshimizu,H.: An interactive facial caricaturing controlled by the behaviors of human vision., A111, QCAV98(4-th International Conference on Quality Control by Artificial Vision), (1998.11)(Takamatsu, Japan)

This Page is inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☒ BLACK BORDERS
- ☒ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☒ FADED TEXT OR DRAWING
- ☒ BLURED OR ILLEGIBLE TEXT OR DRAWING
- ☒ SKEWED/SLANTED IMAGES
- ☐ COLORED OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REPERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

**As rescanning documents *will not* correct images
problems checked, please do not report the
problems to the IFW Image Problem Mailbox**